

THE GOLDEN GATE BRIDGE
The 50th Anniversary Celebration

by

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Research Assistant Caroline Otto

Based on the term paper in the course
GSD 6202 Analysis and Design of Building Structures
by David Hembre, Caroline Otto, Jennifer Payette and Geoffrey Pingree

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THE GOLDEN GATE BRIDGE

1. Introduction

Expecting a maximum of 50,000 people to show-up for the fiftieth anniversary celebration of the Golden Gate Bridge's opening, officials were caught unprepared when 800,000 arrived, sixteen times the estimated crowd.¹ The unexpected number of participants resulted in an unprecedented increase in live load. Bridges, like any other structure, are designed for a specific maximum working load which is not expected to be exceeded during the lifetime of the bridge.

The Golden Gate Bridge visibly responded to the large live load with a reported deflection of its roadway of almost 10 feet at the midspan. In addition, according to witnesses, the cables supporting the roadway were stretched as tight as harp strings.

The situation was compounded by the seventeen mile per hour winds blowing across San Francisco Bay. Suspension bridges are vulnerable to wind loads and, while the bridge was swaying from side to side because of the winds and flattening under the heavy live load, near panic conditions resulted. People were suffering from nausea and claustrophobia in the density of the crowd, making it increasingly difficult to alleviate the situation by directing the people away from the bridge.

María Puentes, intrigued with the photograph of the deflected bridge on the news, decided to employ her skills as a young architect to determine how safe the bridge had been by calculating the stresses resulting from the excessive live load and to verify the deflection at the center of the span. It was difficult to believe that the deflection was actually 10 feet, as it was reported. To obtain the necessary data for the analysis, Puentes started reviewing background information on suspension bridges and the Golden Gate Bridge documents; she also arranged a meeting with her friend Dimitri Kilakos, a structural engineering consultant.

2. Suspension Bridges

2.1. Early suspension bridges

Suspension bridges made from rope have a long history in primitive societies and in military strategy. Rope's strength in tension enabled it to be used for this kind of bridge, but its lack of durability made it only appropriate for

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In many early bridges the roadway was connected directly to the curved suspension chain of the bridge; this made for a difficult passage, however, because of the lack of stability and rigidity. Around 1796 James Finley of Pennsylvania began making bridges with a flat roadway suspended from the cables, giving the suspension bridge its characteristic modern form.

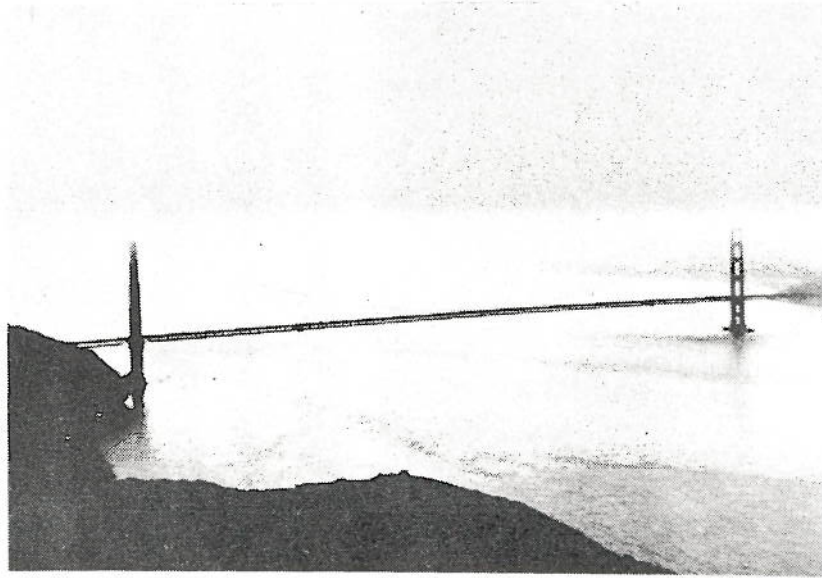


Figure 1: The Golden Gate Bridge.

The revolution in construction, caused by the new materials and engineering breakthroughs of the nineteenth century, was also causing a revolution in aesthetics. The long attenuated proportions of the new bridges and new buildings like the Crystal Palace would find highest expression in the suspension bridges.

The new proportions, however, also led to new problems. An attenuated structure was a more flexible structure and this caused problems, especially in the booming age of the railroads. The concentrated loads of the trains were particularly problematic for the flexible suspension bridges, therefore, suspension bridges were seldom used for railroad traffic unless the roadways were made extremely rigid.

2.2. Steel bridges

The wrought iron suspension bridge design, made from pieces of iron connected by links similar to a bicycle chain, reached its peak in the early 1800s with Brunel's Clifton Bridge which was 630 feet long. The nominal strength of wrought iron (8000 psi) prevented iron suspension bridges from getting any longer. The introduction of high strength steel cable with a

nominal yielding stress of 85,000 psi made long spans, such as the Golden Gate's, possible (Figure 1).

The primary components of steel suspension bridges are:

- a. a roadway
- b. vertical suspender cables
- c. suspension cables, continued beyond each tower and anchored at both sides of the bridge
- d. towers
- e. piers

The roadway carries the traffic loads and it behaves as a continuous beam, structurally suspended by the vertical cables. The vertical cables carry the load of the roadway in tension to the suspension cable which transfers the loads to the towers and its anchorage. The suspension cable is in tension itself and the towers are set in compression (Figure 2). The funicular shape of the suspension cable for a uniformly distributed load along the cable length is a catenary curve.² If the load is uniformly distributed along a projected line, such as the roadway, however, then the funicular shape of the suspension cable is parabolic.



Figure 2: The basic force system for a suspension bridge under a uniform load along its deck.

The described structural behavior of the suspension bridge is accurate when a uniformly distributed load is applied along its length. Variations of the load along the roadway will change the funicular shape of the suspension cables and the bridge itself (Figure 3). The spectrum of variations in the loading can be determined by the loading patterns³ and the ratio between the live and the dead loads of the bridge. The smaller the live load in proportion to the dead load, the smaller the possible load variations. Small variations will always occur, however; and the roadway must have the necessary stiffness to act as a continuous element to minimize excessive deflections as heavy loads pass along the bridge.

² The funicular shape of an unloaded, free-hanging chain.

³ Alternatively loaded and unloaded spans.

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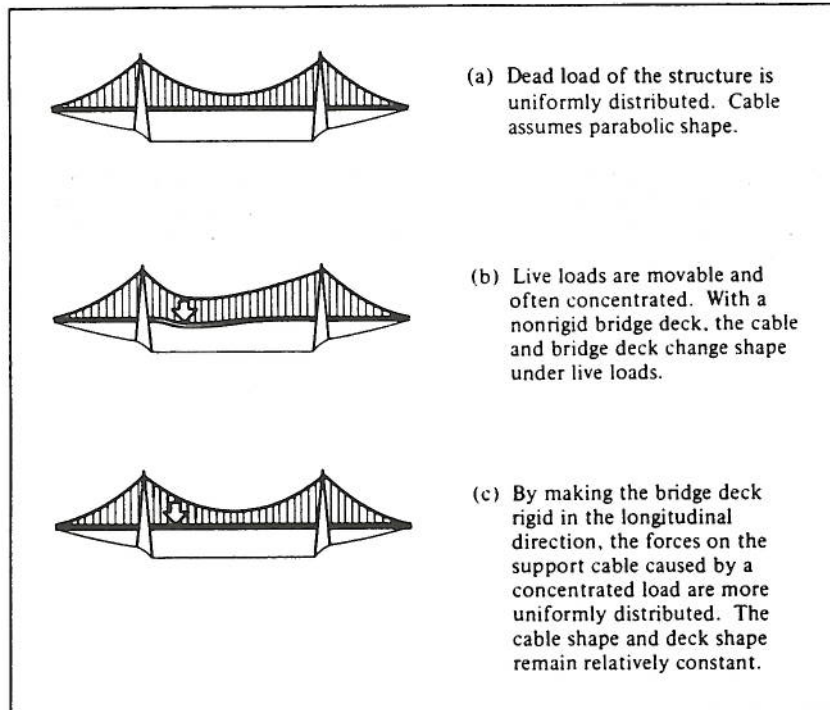


Figure 3: Use of rigid bridge deck.

The suspension bridge is also subject to other loads, such as those generated by wind or earthquakes. The cables cannot provide any lateral stiffness, consequently the roadway is the only structural element to withstand lateral or torsional loads applied on a suspension bridge. Wind loading causes an effect called Karmen Strasse, which is the rhythmic variation of fluid pressure as a fluid passes an obstacle. It is this phenomenon that causes reeds to sway back and forth in a flowing stream and flags to flap in the wind. The danger of this effect on suspension bridges was dramatically demonstrated by the Tacoma Narrows Bridge collapse of 1940. Harsh wind conditions caused the rhythmic twisting of the bridge, whose deck did not have the required stiffness, and led to its collapse. The solution to this problem, as with the problem concerning railroad traffic,⁴ lies in increasing the stiffness of the roadway.

Bridges, as any other structure, are designed for a specific maximum working load, which is calculated as their own weight plus the maximum live load resulting from traffic. They are also designed to withstand wind and earthquake loads of magnitudes that are expected not to be exceeded during the lifetime of the bridge. Bridges' structural members are designed to be stressed in their elastic range⁵ and at a fraction of the proportional limit of the

⁴ Railroad traffic results in heavily concentrated loads passing over the bridge, with most of the bridge either unloaded or experiencing a lighter load.

⁵ Thus, the bridge will not suffer any permanent deformations after the loads are removed.

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steel under these maximum working loads. The ultimate load, on the other hand, is the load under which the structure will fail, thus defining the ultimate capacity of the bridge. The difference between the working load and the ultimate load is the safety margin of the bridge's load bearing capacity.

3. The Golden Gate Bridge

The idea for a bridge spanning the Golden Gate had been considered but remained unpursued for forty years until James Wilking, a journalist, began promoting the idea of the bridge's potential use to residents as well as its beauty. The first serious proposal for the bridge was presented in 1919 after authorities commissioned a survey of the site by Joseph Strauss, a Chicago-based engineer. The bridge would connect San Francisco to Marin County and encourage development north of San Francisco.

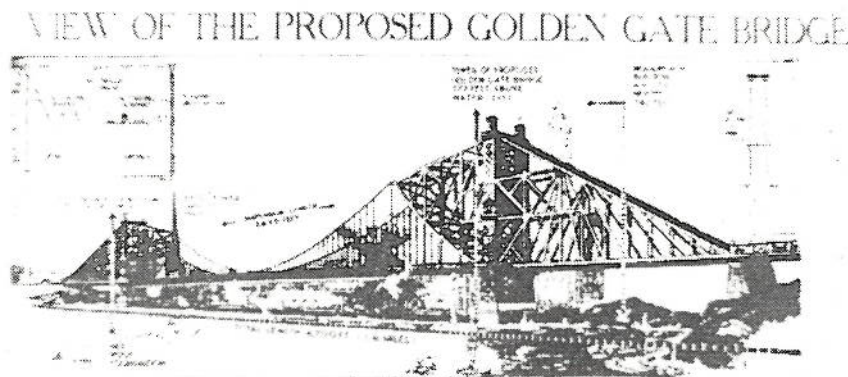


Figure 4: Strauss's first design for the Golden Gate Bridge.

The creation of the bridge was laid on Strauss's shoulders, for whom the greatest concern (and the task for which he should be given a great deal of credit) was the handling of political issues. Unfortunately, he was further hampered by his own first design for the bridge. It featured a combination cantilever/suspension bridge which was described by one writer as "a ponderous, blunt bridge that combined a heavy tinker toy frame at each end with a short suspension plan. (Figure 4) It seemed to strain its way across the Golden Gate."⁶ The bridge commission hid the design from the public for a year; when it was finally revealed, there was widespread dismay.

Strauss, however, continued politicking and soon realized that most of the support for the project would come from the counties north of the bay, not

⁶ *N.Y. Times*, May 24, 1987.

from San Francisco. By 1923, he had gained enough support to begin his real fight for the bridge.

Strauss first navigated his way around the War Department, guaranteeing the department ultimate control of the bridge in the event of war and promising that any damage during construction to the military installations on either side of the bridge would be paid for by the city and local governments.

The next great challenge was to finance the project. A considerable amount of court action was taken as the city and counties sued and counter-sued each other. Finally, the Golden Gate Bridge Company was formed in 1928 and Strauss was appointed chief engineer in 1929, ten years after he had become involved with the project for the first time.

4. The Design of the Bridge

In 1924 Allan C. Rush, architect and engineer, published a proposal for a suspension bridge crossing the Golden Gate (Figure 5). It appeared that everyone, other than Strauss, was proposing or advocating the construction of a suspension bridge. After his official appointment as chief engineer and following several days of discussions with the board of consultants, Strauss also came around to the idea of a suspension bridge.

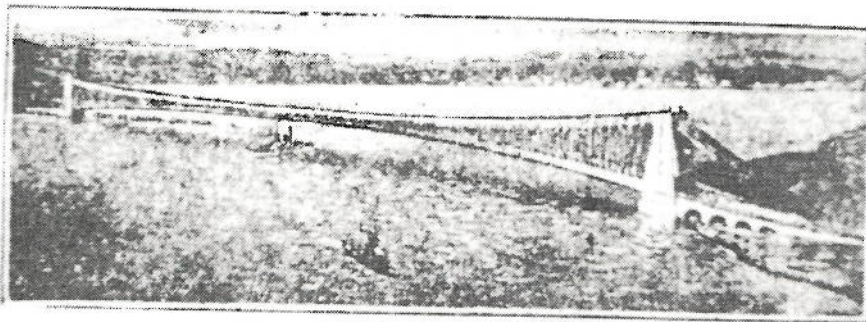
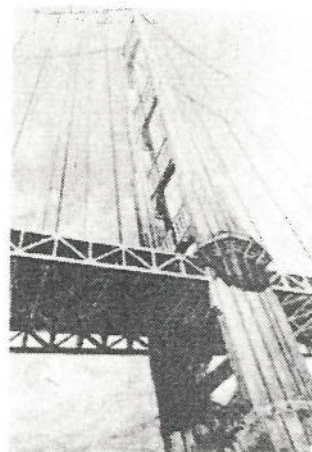
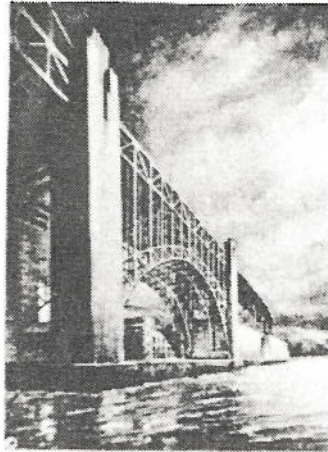
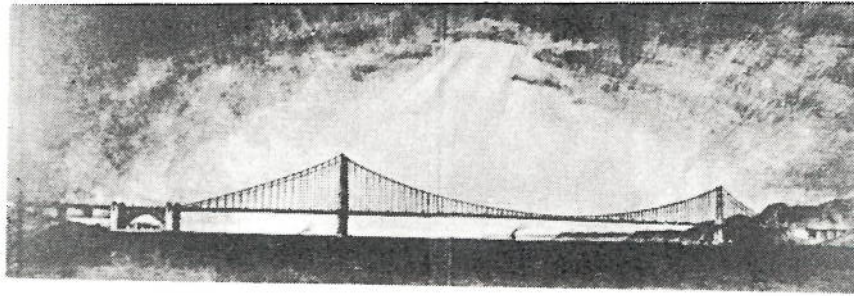


Figure 5: Rush's proposal.

A talented young engineer by the name of Charles Ellis was selected to be Strauss's representative in San Francisco. Ellis, along with architect Irving Morrow, can be credited together with Strauss for the present design. (Figures 6 and 7) "The two proposals for the bridge (Strauss's and Ellis's) seemed to belong to different centuries. The first was massive and complicated and had a fussy nineteenth century sensibility. Mr. Ellis's design was lean, light and simple, of a different higher order. It spanned the channel effortlessly."⁷

⁷ N. Y. Times, May 24, 1987.

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Figures 6 and 7: Morrow's renderings of his early designs.

In 1930, with increased public support for the new design and with an eye on the economic benefits that the construction project would bring, a \$35 million bond issue was approved. Construction began on January 5, 1933, fifteen years after Strauss's original proposal.

5. Construction of the Bridge

5.1. The site and the foundation

The beautiful proportions and lightness of suspension bridges are often heightened by their dramatic sitings. This is certainly true of the Golden Gate Bridge. The Gate⁸ generated some unprecedented challenges in both its exaggerated width and the strength of its seven and a half knot tides that sweep through the passage four times a day. These features would make the bridge one of the most difficult engineering problems ever undertaken.

⁸ The entrance to the San Francisco Bay.

Strauss quickly made two important decisions. First, arguing that the age of mass transit was over, he decided not to include a train service on the bridge. Second, he decided to put the north tower on a stone outcropping off the Marin County shore, despite the opposition's fears that the tower would be built on top of a great crevasse. During construction, an earth slide revealed an old water tunnel and Charles Derleth, one of the three bridge consultants, reported:

We found the tunnel with two feet of water standing in the bottom. Toward the shore of the Golden Gate, the tunnel was disintegrated. But at the site of the anchorage, though exposed all these years, the serpentine in the walls and roof was clean and intact and still showed the pick marks. There is no evidence of softening.⁹

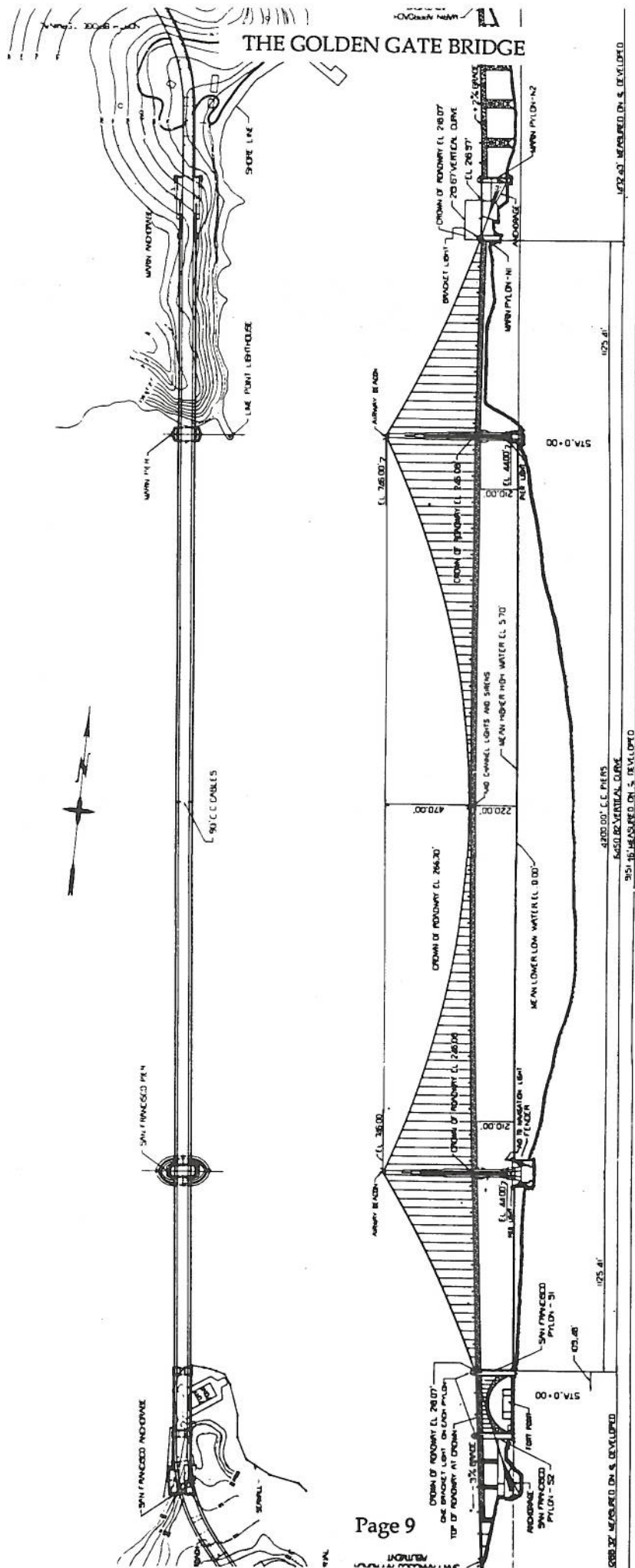
Although placing the north tower there would increase the possible span of the bridge, it would also avoid the tremendous currents that would prove to be such a problem for building the south pier. The currents created conditions that would require a massive seawall to be built around the south pier site. Just the construction of the seawall took an extraordinary amount of time as divers could only work four twenty minute shifts between tides. One storm swept out to sea the entire trestle and crane used to place the forms for the seawall. Cone later recalled:

I'll never forget that day, a fierce storm at sea brought in immense waves, which struck the steel forms with tremendous force.... The trestle groaned and creaked and then suddenly a mountainous wave, higher than the others, hit the forms like a cyclone, and swept it and the end of the trestle into the Golden Gate.¹⁰

The trestle and crane were retrieved and repaired and construction continued. Eventually, the foundations were set and the construction of the towers could begin (Figure 8).

⁹ *The Gate*, p. 175.

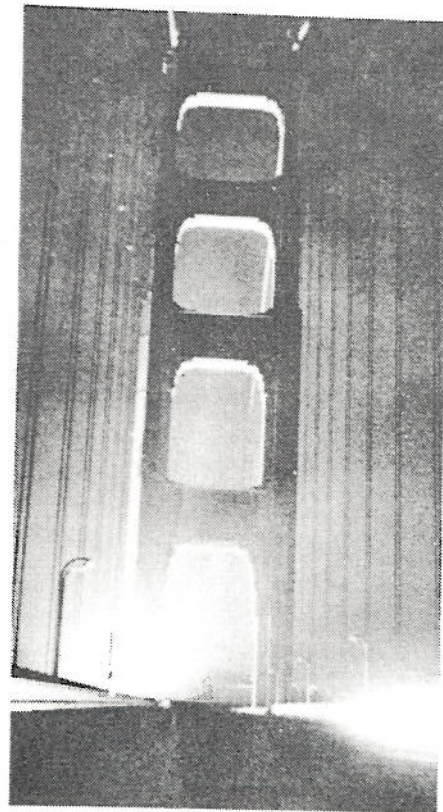
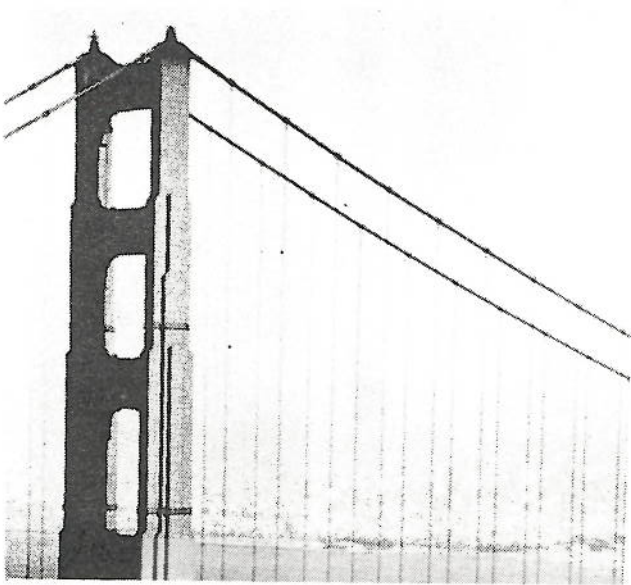
¹⁰ *The Gate*, p. 189.



The Golden Gate Bridge, general plan and elevation of bridge. (Golden Gate Bridge, Highway and Transportation District)

5.2. The piers and the towers

The design of the towers represented the greatest work of both Ellis, the engineer, and Morrow, the architect. Ellis calculated a way to design the towers without diagonal bracing, while Morrow worked out the architectural details. Morrow concluded that "This assumption (that the force of the horizontal winds on the bridge would be borne entirely by the diagonal braces between the two posts) is far from true, because the tower legs, being so very stiff, carry a considerable portion of the shear."¹¹ The tower segments step back gracefully to the top, thus creating its elegant proportions. Simple fluted details were designed to increase the play of light on the bridge (Figure 9). Despite protests, Strauss broke with tradition by giving the job to Morrow instead of his electrical engineers; Morrow's design gave the bridge a look that would be as distinctive at night as its dramatic appearance was by day (Figure 10).



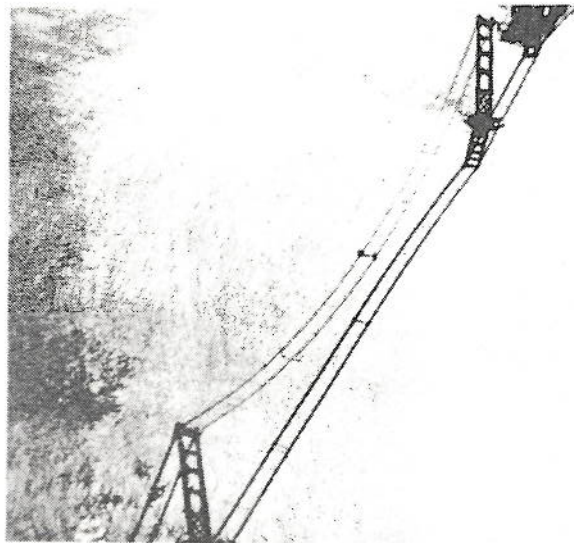
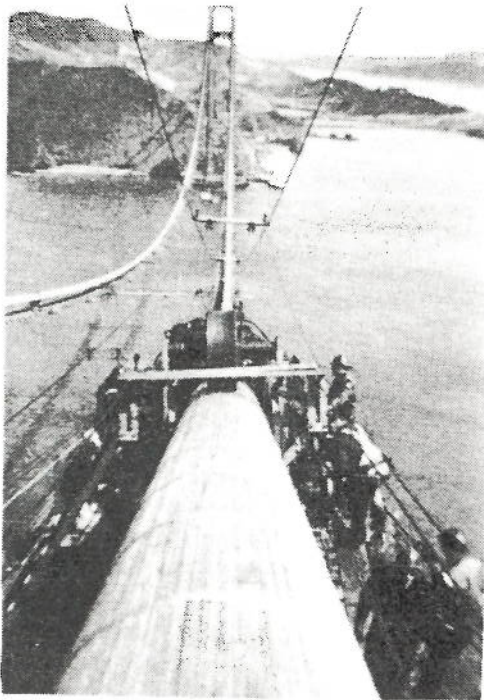
Figures 9 and 10: The play of light on the tower.

¹¹ *The Gate*, p. 145.

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Once the piers were constructed, the towers went up smoothly. The piers rise 40 feet out of the water and the towers reach up for another 690 feet— 500 feet above the roadway. The towers contain 22,200 tons of steel and were assembled with 600,000 field-constructed rivets. The columns of each tower are 90 feet apart and are aligned with the cables. The strength of the mammoth structure was tested even before the completion of the bridge as Frenchy Gales, a head construction worker, recalls:

I was up on the tower when the earthquake hit.... It was so limber the tower swayed sixteen feet each way. There were a lot of seams, all the way to the top. There were twelve or thirteen guys on top, with no way to get down. The elevator wouldn't run. The whole thing would sway toward the ocean, guys would say "here we go!" Then it would sway back, toward the Bay. Guys were laying on the deck, throwing up and everything. I figured if we go in, the iron would hit the water first.¹²



Figures 11 and 12: The cable compressor and the completed suspension system.

¹² *The Gate*, p. 224.

5.3. The cables and the roadway

A pair of giant cables were suspended between the towers and extended to the anchors. The process of spinning the wires to form the massive cables for the Golden Gate Bridge was highly innovative. Two carriages at opposite ends of the bridge pulled wires to the center where they exchanged loops of wire and subsequently pulled them over to the other side. Each carriage went back and forth spinning and building up individual wires into the large cables. The process took seven months, only half the time originally scheduled, which helped the project make up for the time lost on the pier construction. The cables, which are 7,650 feet long, are made from 27,572 solid wires of 0.196 inches diameter and 80,000 psi yielding strength. Formed into 61 strands, they were squeezed by a radial compression machine into one round 36.375 inch cable which was banded every 50 feet by clamps of cast steel (Figures 11 and 12).

Each suspension cable passed over the top of the tower resting on a roller system known as a saddle. Russell Cone, one of the engineers responsible for the design and construction of the bridge, explained the need for the flexibility:

As the cable changes length, the bridge itself moves and deflects and the movements are taken care of by expansion joints and articulated bearings at the main tower. It can adjust itself without damage to quickly applied forces of large dimension. This "giving" or elasticity of the bridge gives strength to the whole structure and absorbs strains and stresses. It's almost a living, breathing thing.¹³

Once the suspension cables were strung, vertical suspenders were hung at 50 foot intervals along each giant cable. The vertical suspenders were composed of a pair of cables, each made of 150 solid wires of 0.196 inches diameter and 80,000 psi yielding strength. These wires were bundled together to form a single cable of 2 and 11/16 inches in diameter. The roadway then began to emerge, built out from each tower and designed to be arched in the middle with a camber of 10.6 feet. During construction, it sagged as it was extended out. Only the top chords of the longitudinal truss supporting the roadway were tightened as the roadways extended outward (Figure 13). The bottom chords were tightened only after the roadway was completed. A 7-inch-deep concrete slab was laid down to form the pavement of the roadway.

The work became even more difficult and dangerous as the number of men working on the bridge increased. Strauss ordered a safety net to be strung under the bridge¹⁴ (Figure 14) and the net saved the lives of nineteen workers

¹³ *The Gate*, p. 235.

¹⁴ The first time that a safety net was used in bridge construction.

during the building of the bridge. Eleven men were lost during construction, however, nine of them when the net gave way under the additional load of a scaffolding that had fallen away from the bridge.



Figures 13 and 14: Roadway construction with a safety net.

Finally, on May 27, 1937, the bridge was opened when 200,000 people skated, pogo-sticked, or walked across the bridge in celebration. The dead weight of the bridge, including the structural and non-structural elements was approximately 19,400 lb/ft, and the expected maximum live load was estimated to be 5,700 lb/ft for the roadway and an additional 2,000 lb/ft for the sidewalks.¹⁵ Strauss concluded in a commemorative poem, "At last the mighty task is done" (Figure 15).

5.4. Further stiffening the roadway

Russell Cone became the managing engineer for the bridge following its completion. One night, gale force winds struck the bridge with gusts up to seventy-eight miles per hour. Cone drove out onto the bridge and became quite disturbed by what he saw:

The center of the bridge was deflected between eight and ten feet from its normal position and was holding this deflected

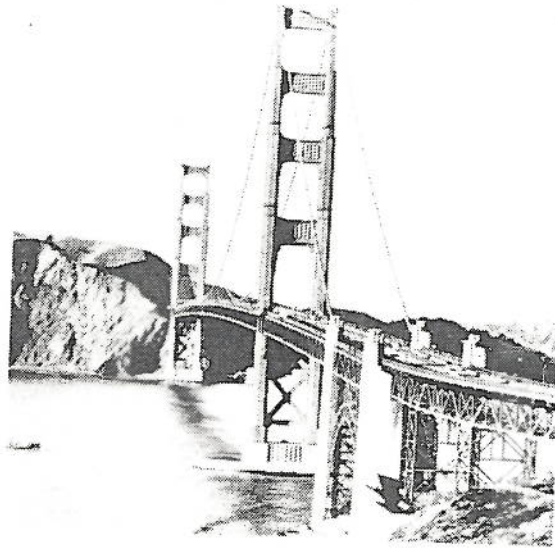
¹⁵ These loads are supported by the main parabolic cables at both sides of the bridge.

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position.... [and that the roadway was] undulating vertically in a wavelike motion.¹⁶

Fearful of what he saw, Cone immediately reported his observations to the bridge committee. The committee had growing concerns regarding the budget and Cone's report was negatively construed by some members of the board, so they decided not to act on it. Two years later Cone was fired, as the committee put it, as an economizing measure.

In the meantime, however, an important event had occurred: the Tacoma Narrows Bridge had collapsed. The rhythmic vibrations that Cone had noticed seemed to parallel exactly those that had brought down the Tacoma Narrows Bridge in the dramatic disaster. A new engineer was brought in to examine the Golden Gate Bridge; he announced that the bridge was in perfect condition. From that day forward, however, it was monitored much more closely during storms. In 1951 a tremendous wind storm rocked the bridge, forcing it to be closed to traffic. After the storm, 5,000 tons of steel lateral bracing were incorporated into the roadway to increase its torsional stiffness (Figure 16). This additional dead weight increased the dead weight of the deck by 1,550 lb/ft to almost 21,000 lb/ft.



Figures 15 and 16: Opening celebration, 1937 and the Golden Gate Bridge today.

¹⁶ *San Francisco Examiner*, "How Safe was the Bridge," May 27, 1987.

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6. The Fiftieth Celebration

The planning for the fiftieth celebration of the Golden Gate Bridge seemed to be as complex as the planning of the bridge itself. Opposition originated from Marin County officials in the form of complaints about the congestion caused by the shut down of bridge traffic as well as from political problems generated within the organizing committee itself, significantly hampering all organizational efforts. Finally it was decided that the event would only be possible if it were scaled down to restrict morning vehicular traffic by permitting only pedestrians to cross between six and eight o'clock am. The publicity was scaled down as well to suit the new objectives of the celebration. Planners, thus, were expecting a turnout of about 50,000 people.



Figure 17. 800,000 people (sixteen times the projected amount) arrived to celebrate the Golden Gate Bridge's anniversary.

On May 24, 1987, however, the organizers expectations were proved incorrect when 800,000 people (sixteen times the projected amount) arrived to celebrate the Golden Gate Bridge's anniversary (Figure 17). The problem was

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compounded by a serious lack of circulation organization. No median strips had been placed on the roadway and as such the huge masses of people crossing the bridge from opposite directions became frozen in a major gridlock (Figure 18). Newspapers reported the event:

Many bridge walkers suffered severe claustrophobia, trapped almost a mile from freedom by a sea of human bodies. 'They had to fight for several hours just to get out' said University of California, at Berkeley, sociology professor, Neil Smelser.¹⁷



Figure 18. The crowd celebrating the Golden Gate Bridge's 50th anniversary.

The large number of participants had a significant physical effect upon the bridge itself as well as a tremendous psychological effect on the walkers.

"The bridge flattened out—its whole arch disappeared," said Gary Giacomini, president of the Bridge District Board. "The bridge had the greatest load factor of its fifty year life. The suspension cables at the center of the bridge were stretched as 'tight as harp strings,' while the lower cables near the tower

¹⁷ *San Francisco Examiner*, "How Safe was the Bridge," May 27, 1987.

seemed to flap in the wind" (Figure 19). Giacomini remembered standing at the center of the bridge, "I thought 'wow' this isn't a good idea!"

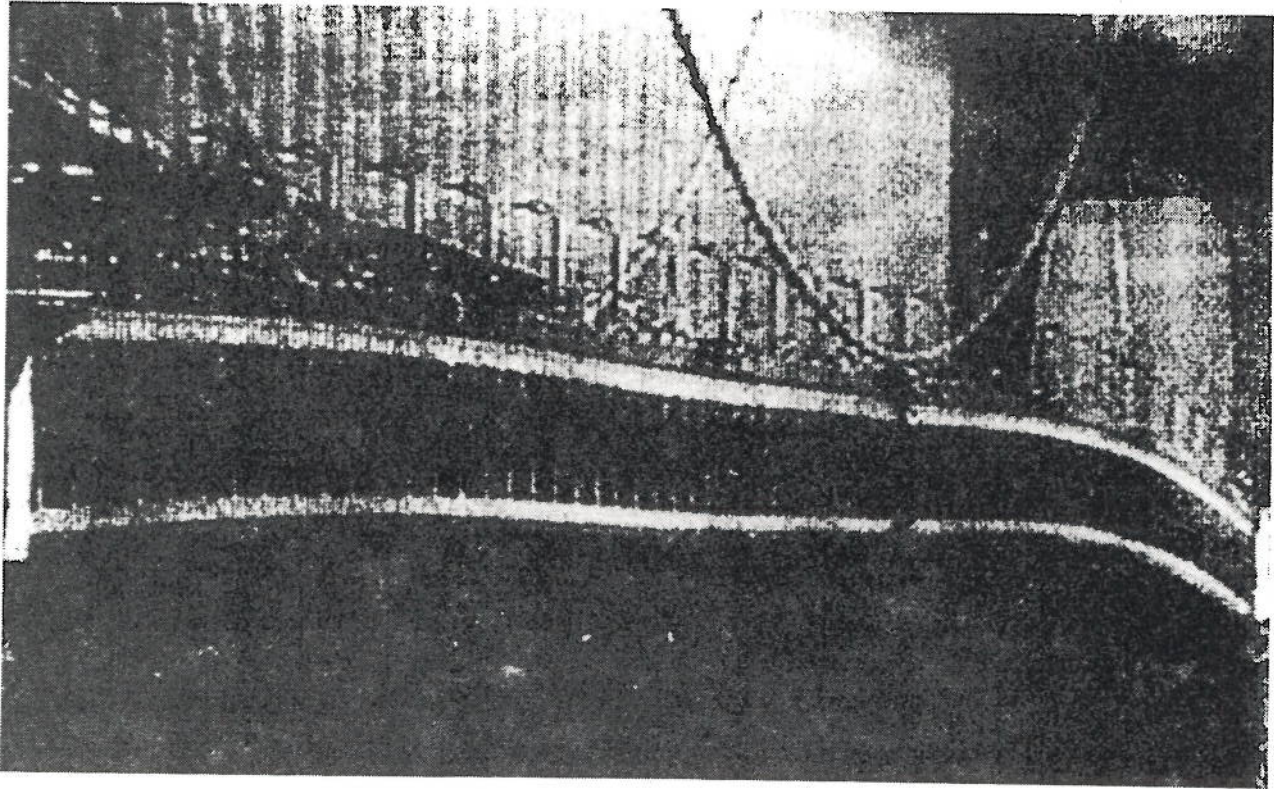


Figure 19. "The suspension cables at the center of the bridge were stretched as tight as harp strings".

Bridge engineers had similar concerns as they busily computed the unexpected live loads incurred by the bridge. Charles Seim (the former state transportation department supervising bridge engineer) who was on the bridge during the celebration, counted heads around him and estimated there were forty people per linear foot of bridge or approximately 6,000 pounds per linear foot¹⁸, while the maximum loading from rush hour traffic is estimated at only 2,200 pounds per foot.

Seim recounted his experience:

I was jammed in there with everyone else during the bridge walk and I was making mental calculations. I knew we were exceeding design loads¹⁹ but I wasn't worried in the slightest. Even at the maximum design load of 5,700 pounds per foot the

¹⁸ According to this estimate there were only 256,000 people on the bridge.

¹⁹ Design load is the maximum load expected to act on the structure during its lifetime.

stress in the cables is only forty percent of their yielding stress²⁰, that's a large factor of safety.²¹

According to Seim, bridge designer Strauss was a conservative engineer. The New York Times²² reported that

The bridge is built to be flexible and can move 15 feet vertically and more than 27 feet from side to side, allowing for changes in weight or the powerful wind that often howls through the Golden Gate, the mile-wide channel from the Pacific to San Francisco Bay.

7. The Engineering Calculations

After reviewing the background information, María Puentes had a discussion with Dimitri Kilakos, a friend who practices structural engineering at Berkeley. When she explained what she would like to do and asked for his advice, he replied:

The estimate on the stresses in the cables is a straight forward task. The roadway is supported by the vertical cables. Thus, knowing the distance between the vertical cables along the bridge, the width of the deck and the estimated applied load on the deck, the force in each cable can be easily determined. Then, you should compare the calculated stress with the yielding strength of the cables, as provided by the manufacturer. For the suspension cables, you can safely assume that the load acts as a uniformly distributed load. Thus, the maximum tensile force, which occurs at the supports of the cable, can be easily determined. Similarly, after you know the tensile force in the cable, you can determine its stress and compare it to the yielding strength of the cable.

Kilakos continued with a few comments on estimating the displacements:

The estimation of the displacements is more complicated. Although you can approximately calculate the deflection at the midspan by long-hand calculations, it is an involved process and I would recommend that you use a computer program. Model half the bridge and position a vertical roller at the midspan to reflect the symmetrical geometry and loading. Use fewer

²⁰ ultimate stress.

²¹ *San Francisco Examiner*, "Bridge 'did just fine,' despite the over load," May 26, 1987.

²² *New York Times*, Tuesday, May 26, 1987, p. A18.

elements than the real bridge to obtain faster results. I recommend you use five equal segments of roadway between the tower and the mid-span²³ and four vertical cables. The area of each vertical cable must be equal to the area of 8.4 actual suspender cables, since the latter are spaced every 50 feet along the bridge. For the roadway between the anchorage and the towers, you should use three equal segments, two vertical cables and the area of each vertical cable must be equal to the area of 7.5 actual suspender cables. Support the main tower on a hinge and use hinges at the ends of the cables. You will also obtain accurate results if you use a truss analysis program instead of a frame analysis program. If you choose to use a truss analysis program, you must include dummy diagonal elements to ensure a proper triangularization. Since the cable is funicularly shaped, the forces on these dummy diagonals will be zero for equal point loads on each joint along the deck and half the load on the joint at midspan. This loading condition corresponds to a uniformly distributed load along the bridge length.

Puentes thanked Kilakos for his valuable advice and started her calculations. She calculated the stresses in the cables by hand, and then she decided to use a computer program to determine the deflections of the bridge. She computed the exact location of the cables, as shown in Table 1 and the properties of the members as shown in Table 2. Her half-bridge model, using a truss analysis computer program²⁴, is shown in Figure 20 and the same model using a frame analysis computer program, is shown in Figures 21 and 22²⁵. Her first step was to check the forces in the cables with her own calculations. She then obtained the displacements of the bridge at various points and she was very surprised by the results.

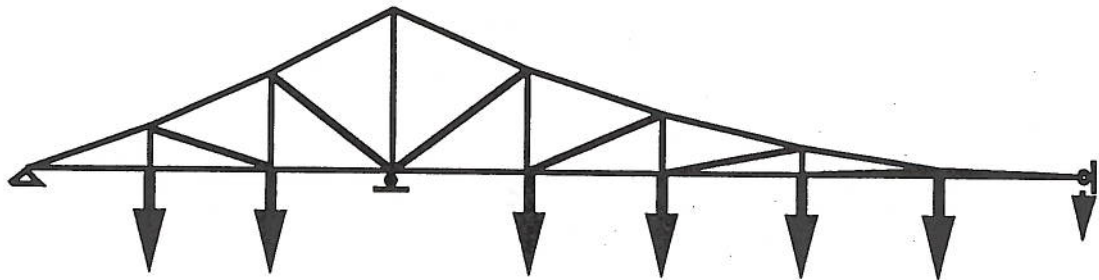


Figure 20: The model of the bridge as a truss and the applied vertical loads at the joints. All diagonal elements are expected to be zero force members, due to the funicular shape of the suspension cable.

²³ Each segment should be 420 feet long.

²⁴ TRUSS_GSD, see the bibliography for the exact reference.

²⁵ MACBEAMS-ETH_GSD, see the bibliography for the exact reference.

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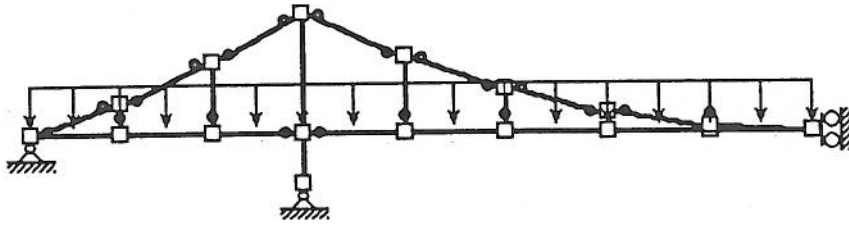


Figure 21: The geometry of the bridge and the applied vertical load. The nodes (shown as squares) indicate a point that two members meet. The round symbol at the end of the members indicates a hinge connection.

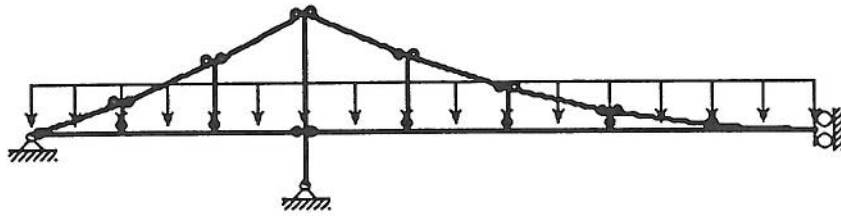


Figure 22: The geometry of the bridge and the applied vertical load, with the symbol of the nodes invisible.

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TABLE 1

The coordinates of the nodes along the cable for the computer model.

NODE	x-coordinate	y-coordinate
1st node (left abutment)	0	0.00
2nd node	375	130.952
3rd node	750	297.619
4th node (tower)	1125	500.00
5th node	1545	320.00
6th node	1965	180.00
7th node	2385	80.00
8th node	2805	20.00
9th node (mid-span)	3225	0.00

TABLE 2

The mechanical properties of the cables.

VERTICAL CABLES

Diameter of individual wire:	0.196 inches
Area of individual wire:	0.030172 sq. inches
Number of wires:	2 x 150
Total area:	9.06 sq. inches
Modulus of elasticity (E):	30,000,000.00 psi
EA:	2.80×10^8 lbs
EI: is not required	

SUSPENSION CABLES

Diameter of individual wire:	0.196 inches
Area of individual wire:	0.030172 sq. inches
Number of wires:	27,572
Total area:	831.90 sq. inches
Modulus of elasticity (E):	30,000,000.00 psi
EA:	2.50×10^{10} lbs
EI: is not required	